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Harnessing Technology and Entrepreneurship for Sustainable Crop Burning Remediation in India

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ABSTRACT

This study explores the intersection of sustainability, technology, and entrepreneurship in addressing crop burning in India. Crop residue burning is a significant contributor to air pollution and environmental degradation, posing severe health risks and economic challenges. This research investigates the environmental and socio-economic impacts of crop burning, while also analysing current technological solutions such as the Happy Seeder and Pusa decomposer, which have shown promise in reducing residue burning. It also examines policy outcomes and entrepreneurial initiatives that aim to scale these solutions, driving adoption among farmers. Through a comprehensive review of relevant literature, data, and case studies, this paper highlights the real-world challenges faced during implementation, including financial barriers, awareness gaps, and policy constraints. It underscores that while subsidies, technological incentives, and policy directives are crucial, they must be complemented by sustained on-ground efforts through a collaborative CRM model that unites government initiatives, external agencies, entrepreneurial contributions, and grassroots-level farmer engagement.

Keywords: Crop burning, Crop residue management, Happy Seeder, Pusa decomposer, technology

Introduction

Each year, 500 million tonnes of crop residue is generated in India (Ministry of Agriculture, 2014, p.1). Much of this comes from India's bread basket, or the Indo-Gangetic plains, where states like Uttar Pradesh and Punjab alone generate 60 million tonnes and 51 million tonnes of residue respectively. While some of this waste is repurposed—as fuel, thatching material, and livestock feed—a large portion is burnt on farms. This leads to several adverse consequences ranging from hazardous air to poor soil health and environmental degradation. Crop burning is also responsible for smog and respiratory complaints in surrounding cities and states, expelling

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harmful greenhouse gases, affecting climate change, and depleting arable nutrients in the soil which harms future crop production. In fact, burning just one acre of land was observed to cause a serious loss in soil nutrients, with numbers as high as 5.5 kilograms of nitrogen, 2.3 kilograms of phosphorus, 25 kilograms of potassium, and 2 tonnes of manure (ICAR, 2018, p.40). Additionally, crop burning was noted as being a prime contributor of air pollution in the National Capital Region (NCR), bringing it to a standstill each winter with air quality reaching "hazardous" levels (Gupta, 2022; Patel, 2023). A 2018 report even attributed 66,000 deaths in India to agricultural burning in 2015 (Chowdhury and Dey, 2016).

To combat this, India's National Green Tribunal banned the practice of crop burning across all five contributing states in 2015 (National Green Tribunal, 2015). In 2023, the Supreme Court also directed the states to put an end to crop burning, with one justice even calling the practice a "murder of the health of people" (Rajagopal, 2023). Several ministry officials also committed to putting an end to crop burning once and for all. In Punjab, over 900 FIRs and fines totalling ₹1.67 crores were also imposed over violations (The Hindu, 2023). Yet, crop burning is still commonplace today, especially between harvest cycles, when farmers need to quickly prepare their fields for the next crop.

Recognising that laws and regulatory compliance alone cannot curb the practice, governmental efforts have increasingly turned to technological interventions. These no-burn alternatives have been heavily subsidised, promoted, and incentivised in order to offer farmers viable tools for sustainable crop residue management (CRM). However, on-ground challenges still remain, affecting the adoption of these technologies and their effectiveness in crop burning remediation.

Both technologies have differing merits, applications, and use cases. Hence, by investigating the status of two such current in-situ technological interventions aimed at mitigating crop burning—namely the Happy Seeder and Pusa decomposer—this paper aims to offer a comprehensive review of CRM technologies in India. By evaluating their successes, failures, challenges, and gaps through relevant data, literature, and research, this paper aims to offer a targeted insight into the scope of these technologies and how their role in crop burning remediation can be enhanced.

Background

Prior to the 2000s, the lack of cost-effective no-burn technologies was a significant barrier to crop burning remediation. However, many alternatives developed in recent decades have offered viable solutions to farmers.

In the 2000s, Happy Seeders, a line of machines which come in different models, held significant potential. Happy Seeders comprise a flail-type straight blade and are directly attached to tractors enabling seed plantation without the need for any prior seedbed preparation (ICAR, 2018, p.1).

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With a capacity to cover 0.4 hectares per hour, they are also easy to operate, lower the percentage of lodging, produce more crop per drop of water, and offer better grain and straw quality (National Academy of Agricultural Sciences, 2017; Tiwari et al., 2019). For greater effectiveness, the machines are combined with the Super Straw Management System (Super SMS). According to the National Academy of Agricultural Sciences, an estimated 60,000 Turbo Happy Seeders, the third-generation model, can cover all the combined harvested rice acreage where crop burning takes place (National Academy of Agricultural Sciences, 2017).

In the National Policy for Crop Residue Management (2014, p.4), the incentivization of Happy Seeders for farmers was recommended to facilitate sustainable in-situ management of crop debris. A central scheme even offers financial assistance covering 50% of the machinery cost to farmers and 80% of project cost to cooperatives and organisations (Ministry of Agriculture and Farmers Welfare, 2018).

With a similar goal in mind, the ICAR recently developed a novel technology. Unlike the Happy Seeder, the Pusa decomposer is a microbial spray which helps farmers decompose crop residue and convert it into organic manure. This low-cost liquid alternative significantly speeds up the decomposition of crop residue. After spraying the solution to 1,935 acres of farmland in 2020 and 2021, the Delhi government reported crop stubble decayed in just 20-25 days, giving farmers enough time to make the fields ready for the next sowing (Indian Agricultural Research Institute, p.4). With the aid of state schemes and partnerships with the private sector, an area of 6.89 lakh hectares was covered in 2021 and 7.70 lakh hectares in 2022 using the Pusa decomposer (Ministry of Agriculture and Farmers Welfare, 2023).

Both these technologies have been critical features of crop residue management since they were deployed. Apart from the government, various external agencies including research organisations, private entities, and entrepreneurs have also participated in the technology to adapt them further to local contexts, improve efficiency, and enable them at scale.

Discussion

Evidence of the successes of Happy Seeders and the Pusa decomposer prompted the Government of India to promote these no-burn alternatives extensively in northern India. In Punjab, where 8 million metric tons of debris is burnt annually, Happy Seeders reportedly saved farmers ₹3500 per hectare compared to conventional methods in the Ludhiana district (Tiwari et al., 2019, p.1). Later analyses showed even greater cost-benefit outcomes, which ranged from ₹10,074 per hectare in the Karnal district of Haryana and ₹8800 per hectare in south-eastern Punjab (Jambagi et al., 2023, p.135; Keil et al., 2020).

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Despite these savings, on-ground realities have often complicated the efficacy and adoption of the Happy Seeder. For instance, in 2020, over 13,000 Happy Seeders and 17,000 Super Seeders were deployed in Punjab (Ghosh, 2021). On paper, these machines had the capacity to manage nearly 17 lakh hectares, or 66 per cent of the non-basmati farmland sown. Despite this, farmers across several districts reportedly burnt crop residue on more than 50 per cent of their land during the same time.

One potential drawback is that financial benefits are distributed unevenly, meaning medium and large farmers reap greater returns on wheat cultivation compared to small farmers. This is significant since as many as 90% of Punjab farmers own less than 1 hectare of land (Kumar, 2019). For such farmers, purchase of machinery, however subsidised, remains expensive. Renting and different modes of ownership have long been proposed by the government to tackle this issue. But these costs are still reported at around Rs 4,000 per acre, meaning many small and marginal farmers still find it difficult to afford the machine (Kumar, 2019).

Happy Seeders also need to be attached to big tractors, which is not ideal in a state like Punjab where the majority of tractors have a capacity of 30-40 horsepower. Additionally, as Jambagi et al. (2023, p.139) find, delays and the cumbersome process of availing subsidies, the requirement of high-power tractors to operate Happy Seeders, and policy bias towards large farmers are all significant impediments to adoption among small farmers. On top of this, Happy Seeders also demand proper technique, the use of correct seed and fertiliser rates, attaining optimum depth of seeding, and properly cleaning the machine after operation, all of which drastically affect its performance (ICAR, 2018, p.7).

Ultimately, these factors indicate that crop burning cannot be solved by policy-level subsidies alone. In other words, technological interventions need to be complemented with on-ground interventions that continuously monitor and address such challenges. Private-public partnerships can play a significant role in creating such targeted interventions. This is evidenced in the TATA Trusts-supported HARIT project, where the Government's efforts in helping farmers across Haryana and Punjab were complemented with training camps, field demonstrations of Happy Seeder machines, and sharing information on crop cultivation practices since 2018 (The Nature Conservancy India). As a result, around 80% of farmers in the pilot area did not burn crop residue, and 58% of farmers accessed Happy Seeder on a rental basis from other farmers. This is a stark improvement compared to the state average, where just one-third of the capacity granted by existing Happy Seeders was covered during the same period in Punjab (Chaba, 2020).

On the other hand, the Pusa decomposer is a microbial solution rolled out to several states on a trial basis in 2020. Licensed to several companies, this technology is a low-cost alternative with four capsules costing ₹20 (Lalwani, 2020). The capsules can be scaled to a 25-litre liquid

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formulation capable of decomposing roughly 1 hectare of rice field (Indian Agricultural Research Institute). Initial evidence surrounding the Pusa decomposer also held significant promise, as 90% of farmers using the Pusa decomposer saw stubble and straw decompose within 15-20 days over the standard 50-60 days, and a yield increase as high as 10%.

However, issues have also been raised by farmers and stakeholders over the years. Among 25 villages that tested the decomposer during October-November 2020 in New Delhi, some farmers reported positive results, but others also claimed the decomposition timeline was impacted by factors like rice variety sowed and temperatures (Pillai, 2020). Later deployments in Punjab and Haryana were not entirely positive either, with decomposition in some cases taking much longer than expected.

However, a key draw for many was that the decomposer was a far more feasible option for smaller fields and marginal farmers than the Happy Seeder, its heavier counterpart. The total cost per acre was also relatively low, estimated at about Rs 300, which includes the cost of preparing the concoction and the labour for spraying (Rai, 2020).

More promisingly, efforts to improve the decomposer are being made by scientists too (Dixit, 2023). But in light of mixed attitudes, future promotion of the Pusa decomposer needs to be complemented by efforts to educate farmers about the formulation and its workings, its suitability and the factors that impact it, address their concerns, introduce the correct techniques, and set realistic expectations regarding its performance. Especially since the IARI noted that even during early trials, many farmers had not followed the exact standard operating protocol of the Pusa decomposer, which can impact its performance (Indian Agricultural Research Institute).

Similar to the Happy Seeder, external agents also have the potential to impact the adoption of the Pusa decomposer. For instance, nurture.farm, an agritech firm tied up with IARI to improvise Pusa decomposer capsules as a ready-to-use spray solution, streamlining the process further for farmers and eliminating contamination and other errors during the mixing stage. (Pandey, 2021) Efforts are also being made by scientists to address farmer concerns and shorten the decomposition window to just over a week.

Both current technologies, the Happy Seeder and Pusa Decomposer, have experienced successes and limitations in addressing crop burning. While the economic benefits of using these technologies are evident and their capabilities promising, overall adoption remains hindered by a range of practical challenges. The continued prevalence of crop burning despite extensive deployment of these technologies, reflects deeper on-ground issues that go beyond simple cost-benefit analyses.

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One key challenge, as outlined in this paper, lies in the uneven distribution of benefits to small and marginal farmers, who constitute the majority of agricultural landholders. Renting these machines, while a proposed solution, still remains financially burdensome for these farmers. Both technology, whether machine or formulation, also necessitates a degree of specialised know-how and training.

The recent CRM guidelines, or rather its blind spots, further elucidate the need to fill these gaps in order for improved outcomes. This includes farmer education and awareness, an important factor for the technologies' successful adoption, which was found lacking in official policy (Ministry of Agriculture and Farmers Welfare, 2023). Others also noted that the capital intensity needed for these technologies and the uphill task of making it lucrative for small-scale farmers was not adequately accounted for (Khanna and Jain, 2024). Contributing states outside of northern India should not go unnoticed either. This includes Madhya Pradesh, where 49,459 crop burning cases took place in 2020, but little to no financial support was allocated (Shrivastava, 2023).

Hence, while subsidies, technological incentivisation, and policy directives are critical components of CRM, they must be complemented by sustained on-ground efforts across diverse regions. These range from training programs to field demonstrations and localised support systems. As evidenced by the data reviewed in this paper, a more collaborative CRM model is the need of the hour, one that brings together government initiatives, external agencies, organisations, and grassroots-level farmer engagement to create an ecosystem where sustainable crop residue management becomes accessible to all.

Conclusion

As analysed in this paper, technological interventions and entrepreneurial initiatives have been a game changer in managing crop residue and alleviating its harmful consequences. However, it is important to note that such interventions need to be closely monitored and adapted to local contexts. Aside from policy, the involvement of multiple on-ground agents is crucial to enhancing communication, adapting the technology, and supporting farmers through education and awareness programs.

Some of the technologies, for instance, the Happy Seeder, might be expensive and unaffordable to small farmers. The Pusa decomposer also involves a significant degree of investment when scaled. Hence, support from the government, whether through subsidies or incentives remains crucial in addressing the challenges of crop residue management.

Additionally, it is equally important to tackle persistent misconceptions about these technologies through a concerted effort at education and awareness programs for farmers. This dual

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approach—combining government backing with targeted educational initiatives—is vital for advancing crop residue management and driving widespread adoption. Addressing these issues has the potential to transform Indian agriculture into a more sustainable practice, revitalise soil health for future cycles, eliminate crop burning, and mitigate its harmful effects.

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